ID: 88081841

Box 23
23-46
Acc. 3

FOREST SERVICE FRAMEWORK FOR INVENTORY & MONITORING

January 5, 2000

Douglas S. Powell

A "White Paper" for the

Washington Office Ecosystem Management Corporate Team &

Interregional Ecosystem Management Coordinating Group

TABLE OF CONTENTS

ACKNOWLEDGEMENTS **2**

EXECUTIVE SUMMARY **3**

INTRODUCTION **6**

BACKGROUND 6
FINDINGS 7

CHARTING A NEW COURSE FOR INVENTORY & MONITORING **9**

STRATEGIC GOAL 9
PRINCIPLES 9

MOVING THE AGENCY FORWARD **11**

BUILDING ON PAST INFORMATION MANAGEMENT WORK 11
CORE VARIABLE CONCEPT 12
INTEGRATED SYSTEMS APPROACH 14
One Size Does Not Fit All *15*
The 4-Way Approach to Integration *15*
Integration Tools *17*
LEADERSHIP AND ORGANIZATIONAL ROLES 18
ACTION PLAN 19

LITERATURE CITED **22**

APPENDICES **23**

APPENDIX A—SIGNIFICANT INVENTORY AND MONITORING EFFORTS OF RECENT PAST 23
APPENDIX B—SIGNIFICANT INVENTORY AND MONITORING EFFORTS CURRENTLY UNDERWAY 26
APPENDIX C—SAMPLE OF INVENTORY STRUCTURE AND RELATIONSHIPS 27
APPENDIX D—CENR MONITORING AND RESEARCH FRAMEWORK 28
APPENDIX E—GLOSSARY 31

ACKNOWLEDGEMENTS

This paper was made possible by the collaborative work of many individuals. Initial work by Richard W. Guldin (*Integrating Forest Service Inventory and Monitoring Programs with the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework, March 1998*) and Bill Sexton (*Forest Service Strategy for Natural Resource Inventories, March 1999*) formed the basis for this framework. A Washington Office team comprised Steve Solem, Rich Teck, Jack Waide, Al Abee, Doug MacCleery, Rob Mangold, Andy Gillespie, and Paul Dunn were instrumental in guiding and directing this effort. Dozens of reviews from throughout the Forest Service and beyond provided comments and suggestions that greatly improved the framework. The author gratefully acknowledges the contributions of all these individuals.

EXECUTIVE SUMMARY

Inventory and monitoring data and information form the foundation upon which the Forest Service depends to carry out its mission. The agency currently faces an increasingly complex set of environmental goals for the lands we manage, the need for analyses at multiple scales, continuous changes in information science and technology, and increased demand by the public for natural resource information. Although the agency has made progress in addressing these issues, the rate of change is not keeping pace, eroding the agency's capability to meet its business requirements and customer's needs. The agency needs to become more efficient in responding and adjusting to these challenges.

Where We Want To Be

The Forest Service needs to have a goal to work toward that defines a future state for inventory and monitoring:

> *Forest Service leadership is committed to using state-of-the-art methods and a systems approach to provide highly credible data and information to meet a wide range of customer business needs in collaboration with our land management partners.*

Accompanying principles elaborate on this vision:

- Utilize a systems approach to inventory and monitoring that adopts a holistic view, recognizes complexity and interactions, and accounts for the dynamic nature and finite capacities of ecosystems.
- Inventory and monitoring are done with the clear purpose of meeting the agency business requirements (at all scales and organizational levels) as determined by the needs of our varied customers and partners.
- Inventory and monitoring are conducted in coordination, cooperation, and collaboration among Forest Service program areas and organizational units and with partners and customers.
- Inventory and monitoring methods and results are scientifically credible and meet rigorous quality assurance and quality control standards.
- Leadership clearly defines the structure for implementing the Framework; provides the resources needed to accomplish the tasks; and is held and holds others accountable for the success of inventory and monitoring programs.

Moving the Agency Forward

The Framework identifies several key ingredients for successfully achieving the desired future state:

1. Building on past information management work.

Building on the EMCT/IREMCG's initial focus on standardizing corporate resource databases and GIS coverages, the Framework expands to include the beginning steps of the information management

stream: resource variable identification, protocol establishment, and data collection. The work to standardize inventories, which populate the databases and construct the GIS coverages, is a logical extension of past efforts.

2. Building on the core variable concept.

Core variables have been established nationally for GIS layers, FIA and FHM programs, and for the RPA Assessment process. These variables are to be collected using standard protocols, which will be flexible enough to allow for the collection of additional data beyond the core set to meet regional and local business needs. The Framework expands this concept to other levels using a "wedding cake" analogy.

3. Utilizing an integrated systems approach.

Another key part of the process toward reaching our strategic goal is taking a systems approach toward integrating our inventory and monitoring activities. One of the major changes the Forest Service needs to make deals with improving inventory and monitoring integration. While cautioning against a "one size fits all" approach, a four-way integration (scale, ecological system, location, and time) concept is proposed. GIS, sampling designs, modeling, and research are described as tools for integration.

4. Establishing clear leadership and organizational roles.

Leadership focus and commitment along with the appropriate organizational structure are fundamental to achieving the strategic goal of this Framework. The agency has made incremental progress in standardizing inventory and monitoring activities; however, without a lead person or group within each region to monitor progress substantial progress will not be made. Similarly, sporadic inventory partnerships with external organizations limit the availability, consistency, and timeliness of information about resource conditions on other lands. Well-organized inventory partnerships with other organizations will improve the Forest Service's ability to consider cumulative effects and broader context in decision-making.

5. Action plan.

Six focal areas for implementation of this Framework and schedule for resolution are depicted in the following table:

Focal Areas	FY2000	FY2001	FY2002
Business Requirements			
Ecological Framework			
Collaboration			
Accountability			
Organizational Roles			
Protocols			

EMCT/IREMCG reached these agreements on November 18, 1999:

1. The white paper, "Framework for Inventory and Monitoring," is adopted as a dynamic foundation for improving the efficiency and integration of inventory and monitoring activities. The principles outlined in the Framework as well as the conceptual model for better integrating inventory and monitoring activities will be used to evaluate and test inventory and monitoring protocols. Any major adjustments to the Framework will be reviewed and approved by the EMCT/IREMCG.

2. Focal areas and schedule of actions outlined in the Framework are adopted. A detailed action plan will be prepared for review and approval by the EMCT/IREMCG by an agency-wide task team comprised of Washington Office, Station, State & Private Forestry, and Regional representatives as well as key external partners.

- This team will act upon the recommendations from the Inventory and Monitoring Institute's Survey of Inventories.
- Priority will be placed on incorporating Montreal Process Criteria into agency programs and transitioning to Primary Purpose principles and budget restructuring.
- The IMI will provide assistance and facilitate the work of this task team.
- R&D (SPPII), S&PF (FHP), and NFS (EMC) will jointly provide leadership of this team.
- Task team membership will be approved by the EMCT at the January 2000 EMCT meeting.
- A draft action plan will be prepared for review by June 2000.
- EMCT/IREMCG will assure team members have time and resources to accomplish assigned tasks.

3. Establish an advisory group for determining priorities and funding within the NFS inventory and monitoring program funded by the NFIM budget line item and recommend to EMCT/IREMCG any program delivery changes deemed necessary.

- The advisory group will begin work on the FY2001 program budget.
- The Director of Ecosystem Management Coordination will provide leadership for this group.
- Membership of the advisory group will be identified by December 15, 1999 and discussed at the December EMCT meeting.

4. Move forward with the R1/R4 IMI pilot program for General Purpose Vegetation Inventory. The Director of EMC will make funds available to support this pilot at the earliest opportunity.

INTRODUCTION

The goal for this document is to describe the Forest Service framework for corporate resource inventory and monitoring. This framework describes the Forest Service's inventory and monitoring efforts so that we may evaluate where we are, where we need to go in order to fulfill our mission and responsibilities, and how to move in that direction effectively and efficiently.

Background

The resources (physical, biological, and human dimensions) that the Forest Service manages are constantly changing. It is through inventory and monitoring (repeated inventories with evaluation) that we discover the status and trends of these resources and begin to understand their relationship to land and resource management strategies and programs.

Four trends require the agency to improve upon its historical inventory and monitoring program:

1. Complexity of environmental goals for which lands are managed.
2. Need for analysis at multiple scales.
3. Implications of the information revolution (age)
4. Increase in the public's appetite for natural resource information

Our customers have become more sophisticated regarding their information requests. If we expect to satisfy our customer needs, our inventory and monitoring system(s), including our spatial analytical capabilities, need to be redesigned.

The Forest Service's history of decentralized organizational structure encouraged land management decisions to be made at the District level. That is where the data and information were required. Recently, a new set of questions is being asked at much broader scales. Spatial resource information is now required beyond the forest boundary to provide needed context. Fully integrated inventory and monitoring systems are now needed to answer questions across a continuum of scales.

Before computers, spatial data consisted of paper maps, and sample plot data were collected with pencil and paper. Data were stored and used locally and rarely shared. With computers came more sophisticated sampling and analytical techniques, faster processing and reporting, and development of corporate electronic databases. Agency-wide computer systems now link the dispersed units of the Forest Service together and encourage sharing of data and information. Similar data exchange capabilities now exist with our myriad land management partners. Technological advances have revolutionized inventory, monitoring, and data management systems, resulting in higher quality data, available more quickly, and at reduced costs.

The information age brings a new discipline to the agency—electronic information management. Recent legislation (Electronic Freedom of Information Act Amendments of 1996, PL 104-231) requires that we make our electronic data available to the public in an accessible format as a public service. The information age is upon us and we are in the process of embracing it.

The Forest Service has previously been involved in many efforts to better manage its inventory and monitoring program (Appendix A) and is now currently engaged in a wide variety of inventory and

monitoring activities (Appendix B). The Inventory & Monitoring Institute (IMI) recently conducted a "survey of inventories" (*Foundations for the Future: Findings from a Survey of Inventories Managed by Regional Offices of the Forest Service, November 1999)* to document existing inventory and monitoring activities occurring at the Regions (see Appendix C for a way of presenting the survey's results).

Findings

A review of all these various past and current efforts leads one to the following findings:

- Forest Service attempts to improve I&M have produced some tangible results (e.g., IMI; FIA strategic plan, national handbook and database; and national handbook for common stand exams).
- The current environment requires more complex, reliable, consistent, accurate, and integrated information, readily accessible in electronic form.
- Data exchange with our land management partners is problematic.
- The Forest Service is poorly positioned to account for efficiencies that can be gained by modifying the current I&M program.
- There is no overall plan for orchestrating the myriad inventory and monitoring efforts currently undertaken by the Forest Service.
- Each organizational unit appears to be pursuing its own I&M agenda with little knowledge or interest in what others are doing.
- The absence of an individual staff managing the agency's diverse I&M activities reflects the fact that the Forest Service is not well organized to provide leadership to manage this program.
- National strategic programs (FIA and FHM) are more integrated, spatially and temporally, than other I&M programs at the region, station, and local level.
- Attribute and spatial data collected on adjacent units are often inconsistent and incomplete.
- Inefficiencies and duplication abound in both sampling design and data collection activities.
- Many data are collected but never analyzed for making decisions or influencing policy.
- The quality of data differs from one field office to another and among resource functions, yet such information is often treated equally when used in making decisions or setting policy.
- Inventories are not focused on answering questions to meet critical objectives. Key issues are ignored while data continues to be collected to answer questions that are no longer relevant.
- Little progress has been made at scaling inventory and monitoring information up from the local level to the national and international level or vice – versa.

These findings emphasize the need to reform our existing I&M program in order to make it more useful and efficient. Unfortunately, for those familiar with Forest Service history, this list of findings is distressingly familiar. Why has the situation not improved? What prevents this agency from making needed changes? These are important questions, yet the answers have been elusive. Some observations that have been offered include:

- The decentralized culture of the agency is not conducive to inventory and monitoring standards.
- Turnover in personnel is high enough that no one remembers previous efforts allowing history to repeat itself.
- There is no commitment to follow national direction and no penalty for not following it.
- There is a lack of commitment by line officers and FS leaders to enforce standards and direction.
- Too many people are managing the process.
- Program authority and responsibility are too diffuse and not properly concentrated.
- It has been difficult to change FSM and FSH direction.
- Forest Service employees, generally, do not view inventory and monitoring tasks as important to the success of the agency.

If these are accurate observations, then the necessary "solution" appears to be less technical and more organizational in nature. There are some organizational changes that should facilitate improvement:

- New standardized (IBM) computing platform with GIS
- Development of corporate data bases (e.g., NRIS, Infra, ALP, FHM, and FIA)
- Movement toward conducting our analyses and decisions using an ecosystem foundation
- Meaningful collaboration with our land management partners and publics
- Leadership that is corporate rather than functional

It will be important to keep these thoughts in mind as we work to avoid past failings and make this reform effort a truly successful one.

CHARTING A NEW COURSE FOR INVENTORY & MONITORING

Strategic Goal

The Forest Service needs to have a goal to work toward that defines a future state for inventory and monitoring:

> *Forest Service leadership is committed to using state-of-the-art methods and a systems approach to provide highly credible data and information to meet a wide range of customer business needs in collaboration with our land management partners.*

Principles

In order to move the Forest Service toward this goal, the agency must subscribe to certain principles relative to inventory and monitoring.

1. Utilize a systems approach to inventory and monitoring that adopts a holistic view, recognizes complexity and interactions, and accounts for the dynamic nature and finite capacities of ecosystems.

A systems approach to inventory is a methodical process of inventory design that encompasses the parts of systems (ecological, social, and economic) and the processes associated with the relations among these parts that results in the ability to be responsive through time and across scales and to be a sound foundation upon which special surveys can be built to respond to myriad issues that arise over time. It means a shift of focus from parts to wholes, from the "interest" to the "capital", from the trees and other plants, animals, water, etc. to terrestrial and aquatic ecosystems that produce these values. This approach utilizes an integrated, multi-scale framework for ongoing inventory and monitoring activities that recognizes the complexity and capacities of ecosystems. Collaboration among all those whose activities affect ecosystems is essential to success.

2. Inventory and monitoring are done with the clear purpose of meeting the agency business requirements (at all scales and organizational levels) as determined by the needs of our varied customers and partners.

Inventory and monitoring are fully integrated into Forest Service business activities and practices and are viewed as essential to success and to support adaptive decision-making. Inventory and monitoring information help the agency meet legal and statutory requirements. Examples include long term measures and annual performance measures established under the Government Performance and Results Act (GPRA); data and information necessary to implement and maintain forest plans following National Forest Management Act (NFMA) regulations; and criteria and indicators for sustainable forest management established under the international Montreal Process. Data are maintained as dictated by management and customer needs and expected rates of change. The collection of basic data (i.e., elements that can be directly measured, observed, or described in a field situation) provides the ability to respond to changes in interpretation and classification and provides the basis for generating long-term trend information. Data are collected once and used often to meet customer needs.

3. Inventory and monitoring are conducted in coordination, cooperation, and collaboration among Forest Service program areas and organizational units and with partners and customers.

Activities are conducted within the Committee on Environment and Natural Resources (CENR) framework (Appendix D) and applicable Federal Geographic Data Committee (FGDC) guidelines to ensure compatibility and data exchange with land management partners. Inventories are conducted within an ecological unit context, not land ownership or administration patterns. Data are collected by the appropriate entity or organization to promote efficiency and data credibility. Before inventories or monitoring are initiated, searches are made for useful data that already exits. Results are served to employees, land management partners, and the public through NRIS, FIA, RPA, or other corporate databases.

4. Inventory and monitoring methods and results are scientifically credible and meet rigorous quality assurance and quality control standards.

Design and inventory procedures are well documented, scientifically peer reviewed, and easily accessible. Data collection and other information management standards are followed. Research and modeling assist in integrating different inventories, scientific methods and research results. Advanced technology and appropriate remote sensing techniques are fully utilized in conducting inventory and monitoring activities. Data integrity is sustained by employing well-trained and qualified personnel. The degree of scientific rigor and quality protocols is appropriate for the particular inventory and monitoring need.

5. Leadership clearly defines the structure for implementing the Framework; provides the resources needed to accomplish the tasks; and is held and holds others accountable for the success of inventory and monitoring programs.

The leadership challenge is to envision the complex components as integral pieces of an agency-wide inventory and monitoring strategy, yet manage the components to serve specific customer needs. Leadership focuses on accountability and insists that efficient, accurate, reliable, and responsive inventory and monitoring systems are used to conduct agency business, such as GPRA performance measures. Program budgets recognize inventory and monitoring activities and appropriate staffing are integral to program implementation. Continuous improvement principles are used to manage inventory and monitoring activities. Clear organizational roles are established to provide timely direction and oversight. The directives system is managed and properly used to document and implement agency policy and protocols.

MOVING THE AGENCY FORWARD

Having defined the future of inventory and monitoring in the strategic goal and principles, we then identified several key ingredients for successfully achieving this desired future state:

1. Build on past information management work of EMCT/IREMCG
2. Build on the core variable concept
3. Use an integrated systems approach
4. Establish clear organizational roles
5. Develop and implement an action plan

Building on Past Information Management Work

EMCT/IREMCG has been building upon an information management foundation developed by the USDA Forest Service Strategic IM Team (1992). A 1997 report for EMCT/IREMCG recognized six steps in producing corporate resource information: 1) resource variable identification; 2) protocol establishment; 3) data collection; 4) data storage; 5) data analysis; and 6) production of models, assessments, maps, and reports (Fig. 1). These components viewed together combine to form an information management system.

Various I&M efforts within the Forest Service have placed emphases on different components of such a system. Two national programs, Forest Inventory and Analysis and Forest Health Monitoring, are instituting integrated information management systems. They have developed standards for all six components and have established linkages that tie all the pieces into a functional package.

Within the National Forest System, the situation is not as far along, but thanks to recent actions by the EMCT/IREMCG, it is moving in that direction. The Natural Resource Information System (NRIS) modules have focused recently on steps #4 and #6. The NRIS Tools Team is focusing on step #5, applications for data analysis. Completion of the Common Stand Exam (CSE) and related work on the use of portable data recorders relate to steps #2 and #3. The NRIS databases provide a direct link to inventories and spatial data by virtue of consistent data standards. With this data storage capability now available, it is time to establish protocols for integrated approaches to inventory and monitoring (steps #1-3). Additionally, the scope of this framework is to broaden the inventory and monitoring components (steps #1-3) beyond NFS, so that other inventory and monitoring programs (such as FIA and FHM and those of other agencies) will be integrated in as seamless a manner as possible.

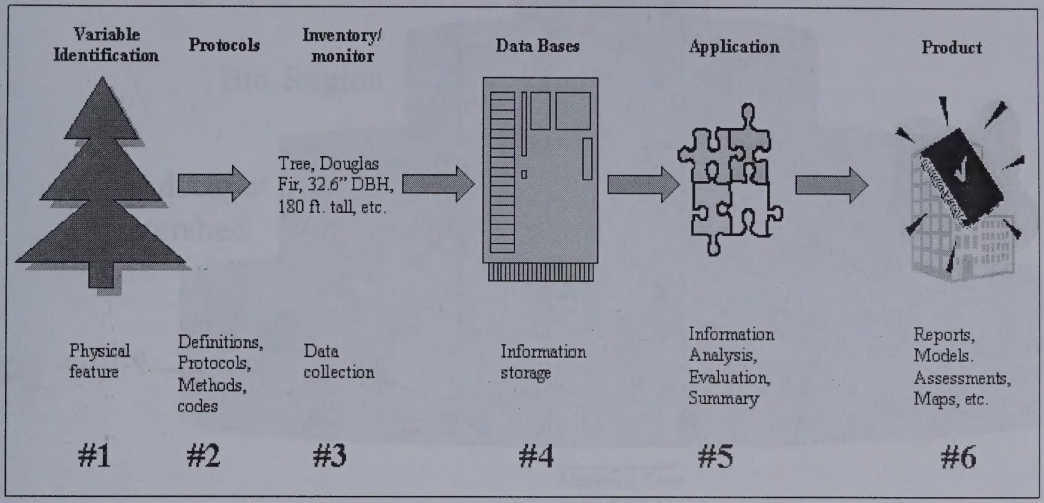


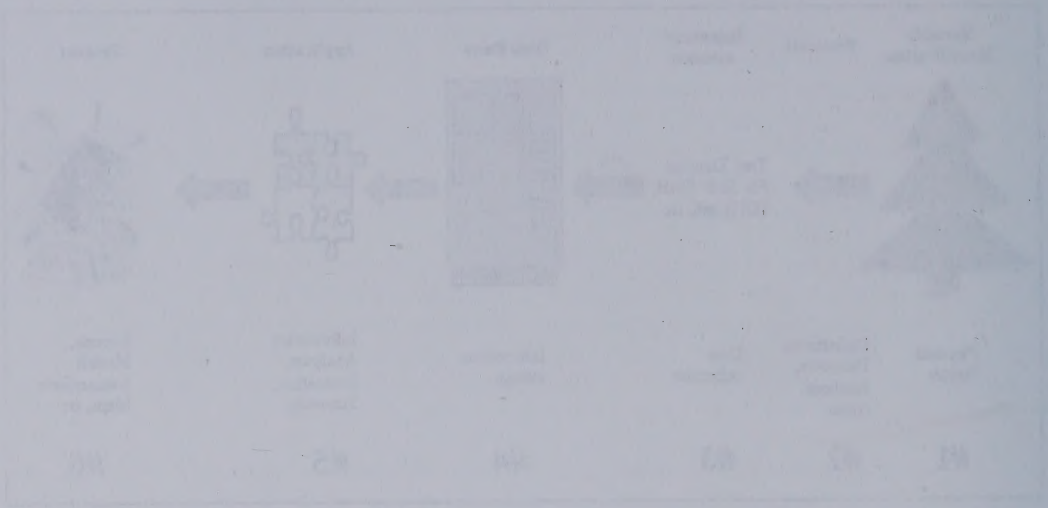
Figure 1. Framework for describing the process of identifying, collecting, storing, analyzing, and producing information (adapted from *An Operational Framework for Managing Forest Service Resource Information,* EMCT, June 1997).

Core Variable Concept

One way to work toward an integrated system without sacrificing customer needs is the core variable concept. Defining a set of core variables that satisfy agency business requirements ensures system consistency. These variables will be collected on all lands using standard protocols. The protocols will be flexible enough to allow for the collection of additional data beyond the core set to meet regional and local business needs. The core variable concept applies to both spatial and tabular attribute data.

EMCT/IREMCG were instrumental in the success of identifying a core set of standard GIS layers that would be applied nationally throughout NFS. The FIA and FHM programs have also identified a core set variables that they are instituting in their inventory and monitoring across all land ownerships. And the national assessment mandated by the Forest and Rangeland Renewable Resources Planning Act (RPA) relies on a core set of data that can be aggregated from diverse inventories to provide a national description of our forest resources. This framework builds upon these efforts by expanding the process to other levels. Figure 2 shows how this concept might work using a "wedding cake" analogy.

The small, top layer represents inventories of all types that produce data and information for the whole country. Data that are aggregated upward from inventories conducted at finer levels below define a set of core variables. Standards for definitions, acquisition protocols, and quality control objectives would



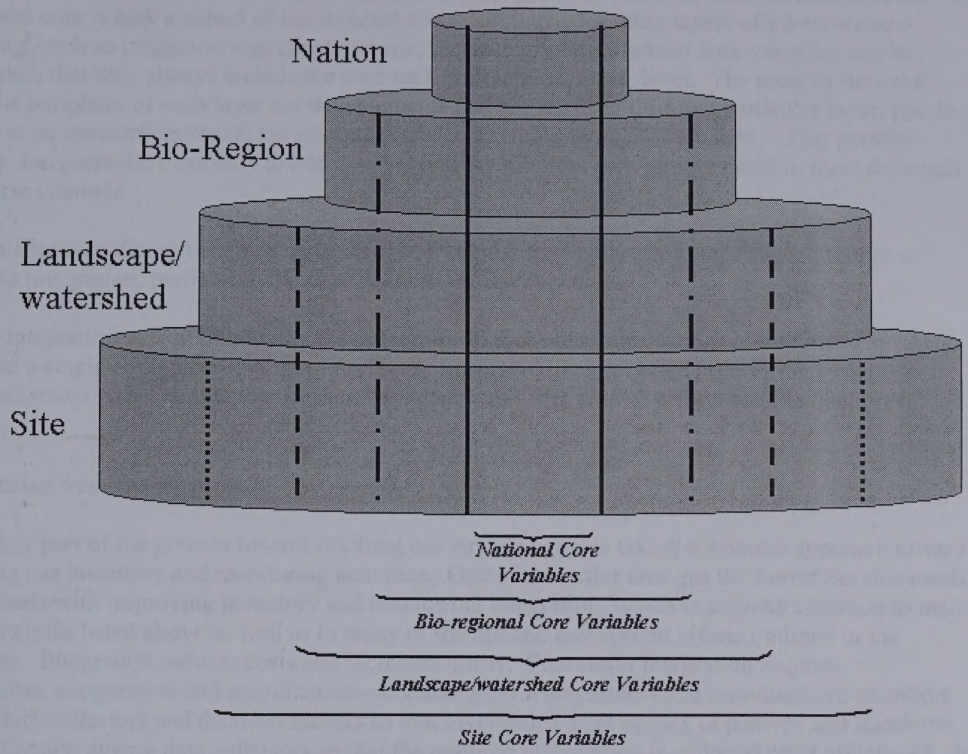
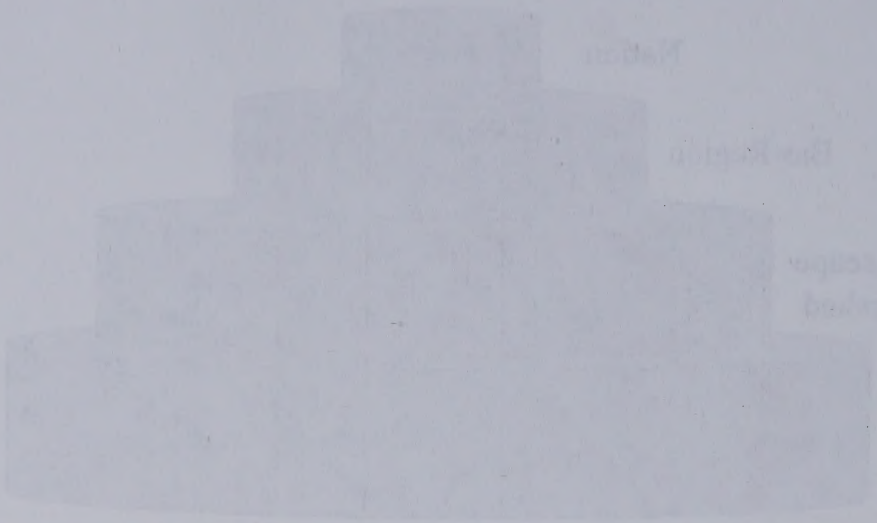


Figure 2. Core variables can be defined for a variety of levels or scales of inventory and monitoring.

be mandated for these core variables, so that consistency would be assured. For example, timber volume for national RPA reports is calculated from basic data such as diameter at breast height (DBH). This data element is also common to timber inventories at lower levels, all the way down to a specific site inventory. So it makes sense that whenever and wherever DBH is measured, it is done the same way. Another example is the agency-wide core set of geographic information system layers that have been established by the EMCT/IREMCG (GIS Team 1997). A large effort to identify national core variables occurred in the late 1980s with the development of the Resource Inventory Handbook (FSH 1909.14), and FIA has recently identified core variables for its national program. Data needed for GPRA long-term and annual performance measures would also included in the national core.

The next layer of the cake represents bio-regional inventories. These might be like some of the large-area assessments that agencies have conducted. They would generally have a larger pool of variables, mainly because there are more diverse customer needs than nationally, and so the layer is larger. While each of these inventories is done in different areas for different purposes, there is a subset of all variables that are common. These would compose the core set of bio-regional variables represented by



the part of the cake within the dash-dot lines. It is a larger group of variables than the national core, but the national core is now a subset of the regional core. Similarly, for other layers of inventory and monitoring, such as landscape/watershed and site, increasingly larger sets of core variables can be defined such that they always include the core set from the next higher level. The parts of the cake around the periphery of each layer are data elements that are important for that particular layer, but do not need to be standardized (with the exception of documenting requisite metadata). This permits inventory designers the flexibility to add data beyond the minimal core requirements to meet the needs of a diverse clientele.

This identification of core variables and subsequent standardization are key steps needed to move toward the integration, particularly vertical integration, across scales.

So while integration is worth pursuing, the outcome will more likely be a series of integrated systems rather than a single comprehensive one. And these integrated inventory and monitoring systems must also be integrated with the other business of the agency and with similar efforts outside the Forest Service.

Integrated Systems Approach

Another key part of the process toward reaching our strategic goal is taking a systems approach toward integrating our inventory and monitoring activities. One of the major changes the Forest Service needs to make deals with improving inventory and monitoring integration, which is a thread common to many of the principles listed above as well as to many of the historic and current efforts outlined in the appendices. Integration reduces costs and increases utility. Successful integration requires collaboration, cooperation and coordination—collaboration with partners and customers, cooperation between data collectors and decision makers so that inventories meet agency objectives and standards, and coordination among data collectors so that the required information is gathered most effectively. It also requires an organizational structure that can effectively manage the process.

Collaboration is needed because no single partner is able to collect all the data sufficient for its needs. All partners, including the Forest Service, need to be able to import and export data from other sources. Collaboration is essential to make this data exchange work efficiently.

Cooperation is needed 1) to establish minimum requirements for meeting information needs, 2) to establish inventory standards providing uniformity between data collectors, 3) to develop quality requirements against which inventories can be evaluated, and 4) to increase utility of resulting information.

Coordination is needed to improve cost effectiveness by eliminating redundant data collection and reporting. Involving all interested parties, clearly identifying intended use, defining areas of responsibilities, and designing inventories that are multi-purpose, all improve the efficiency and effectiveness of the overall program.

Through standardization information becomes more valuable. Data can be compared and/or combined and made available to more people. Definitions, classification, and measurements require standardization; but to encourage innovation, flexibility in how those standards are met must be allowed.

Standardization also requires an agency structure capable of effectively setting standards and enforcing compliance with them.

This call for integration does not detract from but rather reinforces those efforts that have already achieved some level of integration. For example, the terrestrial ecological unit inventories, known as ECOMAP, are inventories that successfully integrate climate, soils, geology, geomorphology, and potential vegetation. The National Cooperative Soil Survey is another example of strong interagency collaboration in many areas. Efforts in Regions 3,5, and 6 demonstrate the inventories can be designed to collect information in a progressive manner so that data can be used to address multiple issues. The Forest Service needs to recognize successful models like these, build upon them, and integrate them into the larger resource information system.

One Size Does Not Fit All

The integration of resource inventory and monitoring has limitations that must be explicitly recognized. Given the diverse needs for information about myriad resources along both spatial and temporal continua, it is not possible to design and implement an integrated inventory system that will meet all user needs or agency business requirements. For instance, reliance on a grid-based sampling frame might be an improvement over today's situation, but it would not answer all questions about resources that are rare, ephemeral, of low density, mobile, linear, or pertaining to the human dimension. Specialists in these areas often rely on disparate and ancillary inventories. Integration of such inventories collected at different sample times, scales of resolution, and levels of locational accuracy is problematic.

It is possible, using logical planning, to make such integration more defensible and useful (Lund 1998). This might include:

- Conducting user surveys at specific locations or employing user surveys geo-referenced with extensive area-based resource inventory attributes.
- Stratifying data collection to ensure that some sampling occurs during the season(s) when resources are readily identifiable, such as sub-sampling herbaceous species in each ecological community in the spring.
- Incorporating indices (such as habitat) for rare, ephemeral, or low-density resources rather than conducting population censuses. These efforts, though, are sub-optimal as they lack actual sightings, and the relationships between the resource and corresponding index must be validated.
- Linking resource attribute data from one resource inventory to another related resource through standardization of definitions and geo-referencing of all samples.
- Establishing protocols (through research and modeling) that link disparate surveys.

The 4-Way Approach to Integration

Because inventory and monitoring are so diverse in terms of purpose, discipline, extent, type, and method, there are many components that must be factored in to the integration process. A useful way of doing this is to consider four commonly encountered themes: 1) scale, 2) ecological system, 3) location, and 4) time. These are represented schematically in Fig. 3, which is adapted from Lund (1985). Each block represents a particular inventory, and it is replicated at the different scales, locations, and times. If

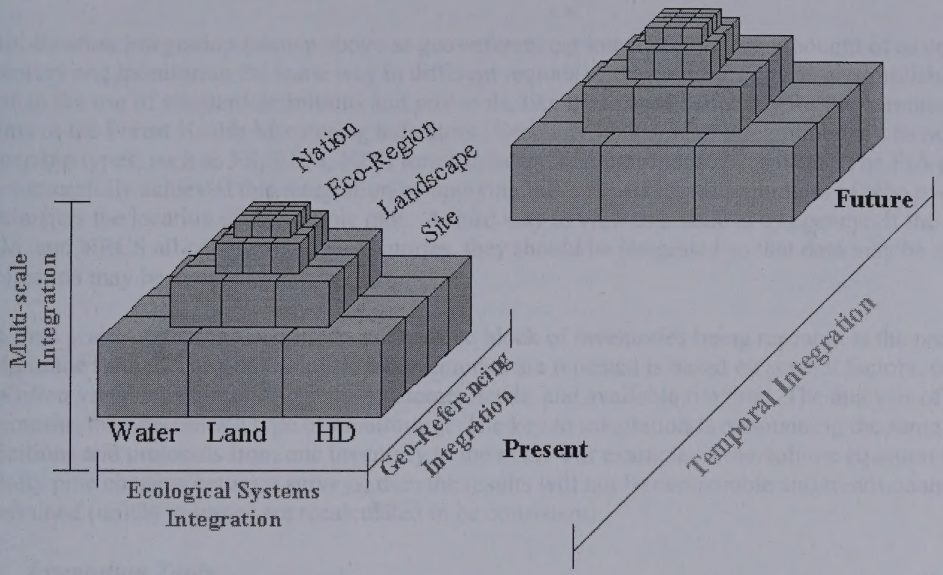


Figure 3. Schematic representation of 4-way integration of inventory and monitoring (adapted from Lund 1985),

integration can be achieved across all of these themes the result will be the integrated, multi-scale inventory and monitoring system set forth in principle #1 above.

Multi-scale integration can take a variety of forms. In Fig. 3 it is depicted as areas (nation, eco-region, landscape, and site). It could be any sort of hierarchical classification, such as Ecomap levels or taxonomic levels or organizational units. Integration across this theme is achieved through the use of core variables (see description above) with standard definitions and measurement protocols. This is sometimes referred to as vertical integration.

Ecological systems integration can also be considered in numerous ways. In Fig. 3, there are three basic systems represented: aquatic, terrestrial, and human dimensions. This could also be viewed as traditional functional inventories such as soil, vegetation, recreation, wildlife populations, water, air, and minerals. Yet another way is by components of the holosphere: biosphere, atmosphere, lithosphere, hydrosphere, and cultural/social sphere (as is being used in the Sierra Nevada monitoring strategy). This

type of integration (often called horizontal integration) can occur when data are collected (such as by visiting the same sample area at the same time), when data are stored (such as linkages among the different NRIS data modules), or during analysis (such as linking wildlife habitat data to population data through modeling).

Multi-location integration (shown above as geo-referencing integration) can be thought of as conducting inventory and monitoring the same way in different regions of the country. This is accomplished through the use of standard definitions and protocols, like those used nationally for the common stand exams or the Forest Health Monitoring indicators. Secondly, this type of integration may be across ownership types, such as FS, BLM, NPS, forest industry, and non-industrial private. The FIA program has successfully achieved this integration by applying the same standards regardless of who owns or administers the location of the sample plot. A third way to view this scale is by agency. If the FS, BLM, and NRCS all conduct range inventories, they should be integrated so that data may be shared and duplication may be avoided.

The final scale—temporal—is shown as the same block of inventories being repeated at the present and again in the future. The number of times inventories are repeated is based on several factors, such as how often variables of interest change, customer needs, and available funding. The analysis of repeated inventories then becomes a type of monitoring. The key to integration is maintaining the same definitions and protocols from one inventory to the next. For example, if the volume equation for loblolly pine changes between surveys, then the results will not be comparable and trends cannot be ascertained (unless volumes are recalculated to be consistent).

Integration Tools

The geographic information system (GIS) is a tool that is very useful for integration of spatial inventories. Many of our inventory and monitoring activities are designed specifically for use with GIS. Lang (1998) describes several functions of GIS one of which is displaying different map files (layers) for joint analysis. By putting spatial data in a GIS (which is also an integrated system) where it can be organized, analyzed, and mapped, specialists can find patterns and relationships that were previously unrecognized. This technique has application for the ecological system (or horizontal) integration described above. And when GIS is coupled with core variables (as in the standard core GIS layers), it is a powerful tool for multi-level or vertical integration as well.

Another possible tool for integration is the single intensity grid. The Forest Inventory and Analysis (FIA) program uses a network of 125,000 permanent sample plots, which are laid across the country wall-to-wall at intervals of approximately 5 km. This is referred to as the single intensity grid. Because it covers all ownerships, vegetation types, ecoregions, counties, etc. and maintains national standards for core variables and protocols, it is a vertically and horizontally integrated inventory and monitoring program for vegetation. These favorable attributes make the single intensity grid a potential base sampling frame for other types of surveys, which would contribute to ecological system integration. The Northern Region is working with the Inventory and Monitoring Institute to develop a strategic ecological system inventory that applies the FIA grid in this way and has discovered significant cost savings to this approach. Another advantage of such a grid system is that adding plots systematically among existing ones can increase the sampling intensity. Using this option leaves one vulnerable to the

problems discussed earlier in "One Size Does Not Fit All." The point is that this approach may work for integrating some, but not all, functional inventory and monitoring efforts.

Modeling and research are also powerful integrating tools and are integral to the CENR framework described in Appendix D. For example, sets of photography or satellite imagery from different points in time can be used to detect changes. However, such comparisons cannot generally indicate why a specific change occurred. Other data, from more intensive inventory and monitoring sites, are essential for quantifying the extent, distribution, condition, and rate of change of specific environmental properties and for understanding change processes over large areas. To successfully link information from photography/videography/imagery and the probabilistic surveys of field sites, researchers have developed a number of integrating models.

Research is a necessary precursor and often an adjunct to modeling that operates at several different levels in the context of an inventory and monitoring framework. At one end of the spectrum, research on new sensor designs helps determine what imagery might become available and how to best take advantage of increased image resolution. At the other end of the spectrum, basic research results in plant physiology, pathology, and other biological sciences are incorporated into intensive site monitoring to better understand how stress may influence biomass production, health, and condition and relates those results to changes detected at coarser inventory scales. Only through fully integrating research into inventory and monitoring programs can the tools be developed to understand what is observed, to understand why a specific change is occurring, and to understand the causes of the effects observed.

Leadership and Organizational Roles

Implementing fundamental changes in agency culture and behavior demand critical leadership attention. Issues related to organizational responsibilities are more significant than any of the technical issues described above. The current distributed authority and responsibility for inventory programs throughout the agency provides significant opportunities for individual program areas and Regions to devise unique organizational structures, policies, and operations. This legacy served the agency well in addressing issues of a local scale with limited ecological context, or focused on specific national program areas. Efforts to coordinate across Regions and program areas have generally been limited to collaboration required by high-profile bio-regional assessments. The costs associated with this coordination to develop standard resource information displays, maps, and national assessments; and to generate findings have been substantial and are well documented. Where we have made progress, most notably in FIA and FHM, clear organizational roles and responsibilities and a leadership commitment have been essential ingredients.

Relatively few positions within Regional Offices are designated to lead and manage inventory programs. Where these positions are being implemented, the agency is posturing itself to benefit from coordination prior to crisis situations or one time assessments. Such efforts foster mutual development of protocols, promote consistent expectations and management practices across Regions, and facilitate credible reporting of inventory programs and data. These results would be further enhanced with improved coordination across program areas at the national level. Building upon existing successes would suggest the need for each Region to designate a person or team to be responsible for inventory program coordination across NFS program areas, State and Private Forestry, and Forest Service Research and

Development. The decision to establish these positions would improve inter-regional coordination, aid partnerships with external organizations, provide oversight of interagency agreements, improve attainment reporting, and facilitate informed priority setting and NFIM budget allocations.

Designation of a person, team, or program staff at the national level and clearly describing their roles in coordinating the inventory program across Deputy areas, program areas, Stations, and Regions is essential. Partnership development with external organizations would also fall under the jurisdiction of this organization.

Coordinating a comprehensive review followed by a subsequent consolidation of all Forest Service Manual and Handbook direction related to inventory into a single file designation would improve awareness and application of inventory direction, and expose opportunities for improved integration between program areas

Sporadic inventory partnerships with external organizations limit the availability, consistency, and timeliness of information about resource conditions on other lands. Thus, there is a need and opportunity to increase permanent long-term partnerships with other organizations such as NRCS, BLM, EPA, USGS, NPS, FWS, tribal governments, BIA, State agencies, and other organizations. Well-organized inventory partnerships with other organizations improve the agency's ability to consider cumulative effects and broader contexts in its resource management decision-making.

Leadership focus and commitment along with the appropriate organizational structure are fundamental to achieving the strategic goals of this framework. An acknowledgment of the varied customer and business needs of the agency and the ability to be responsive to these customer needs must occur.

Action Plan

This framework has identified several findings where change and improvement are clearly needed, and outlines a new course for the agency through the adoption of key principles and ways to better integrate our inventory and monitoring efforts. Our goal is to design an integrated resource information system that will meet the agency's resource inventory, monitoring, and analysis needs in the most cost effective manner possible. There is no way to devise an inventory that meets everyone's needs. Through integration efforts, we can streamline our inventory programs and make them much more efficient. The concepts are simple; the implementation is more challenging.

How do we begin down this path and make progress toward our desired future situation?

Six focal areas for implementing this Framework emerge from the IMI/IREMCG survey of regional inventories; national program manager review and input; and experiences of implementing Forest Inventory and Analysis (FIA), Forest Health Monitoring (FHM), and the Natural Resource Information System (NRIS). The basic pattern of actions and schedule for resolution is depicted in the following table. In general emphasis in FY2000 is focused on organizational issues and inventory protocol development would be addressed in FY2001 and FY2002.

Focal Areas	FY2000	FY2001	FY2002
Business Requirements			
Ecological Framework			
Collaboration			
Accountability			
Organizational Roles			
Protocols			

Factors leading to the establishment of this schedule and time frames include:

- The EMCT/IREMCG agreed to complete implementation of NRIS and Core GIS layers by 2005.
- A critical implementation issue identified in Regional NRIS Implementation Plans is the migration of legacy data sets into NRIS databases. By establishing a goal for "corporate" inventory and monitoring systems to be completed by FY2002, new inventory data will be standardized, thereby reducing the data migration needs associated with NRIS.
- Proposed NFMA regulations increase emphasis on adaptive management principles and monitoring systems. The regulations are projected to be finalized in FY2000. The schedule for implementation of new inventory and monitoring protocols would need to be coincident with these new requirements.

Based on this, the EMCT/IREMCG reached these agreements on November 18, 1999:

1. The white paper, "Framework for Inventory and Monitoring," is adopted as a dynamic foundation for improving the efficiency and integration of inventory and monitoring activities. The principles outlined in the Framework as well as the conceptual model for better integrating inventory and monitoring activities will be used to evaluate and test inventory and monitoring protocols. Any major adjustments to the Framework will be reviewed and approved by the EMCT/IREMCG.

2. Focal areas and schedule of actions outlined in the Framework are adopted. A detailed action plan will be prepared for review and approval by the EMCT/IREMCG by an agency-wide task team comprised of Washington Office, Station, State & Private Forestry, and Regional representatives as well as key external partners.
   - This team will act upon the recommendations from the Inventory and Monitoring Institute's Survey of Inventories.
   - Priority will be placed on incorporating Montreal Process Criteria into agency programs and transitioning to Primary Purpose principles and budget restructuring.
   - The IMI will provide assistance and facilitate the work of this task team.
   - R&D (SPPII), S&PF (FHP), and NFS (EMC) will jointly provide leadership of this team.
   - Task team membership will be approved by the EMCT at the January 2000 EMCT meeting.
   - A draft action plan will be prepared for review by June 2000.
   - EMCT/IREMCG will assure team members have time and resources to accomplish assigned tasks.

3. Establish an advisory group for determining priorities and funding within the NFS inventory and monitoring program funded by the NFIM budget line item and recommend to EMCT/IREMCG any program delivery changes deemed necessary.

- The advisory group will begin work on the FY2001 program budget.
- The Director of Ecosystem Management Coordination will provide leadership for this group.
- Membership of the advisory group will be identified by December 15, 1999 and discussed at the December EMCT meeting.

4. Move forward with the R1/R4 IMI pilot program for General Purpose Vegetation Inventory. The Director of EMC will make funds available to support this pilot at the earliest opportunity.

LITERATURE CITED

CENR. 1997. Integrating the Nation's environmental monitoring and research networks and programs: a proposed framework. National Science and Technology Council. Washington, DC. 102 p.

Helms, John A., ed. 1998. The dictionary of forestry. The Society of American Foresters, Bethesda, MD., 210 p.

GIS Team. 1997. Recommended core data standards for GIS applications. Report to the Ecosystem Management Corporate Team & Inter-regional Ecosystem Management Coordinating Group dated October 27, 1997, Washington, DC. 64 p.

Juran, Joseph M. and A. Blanton Godfrey, eds. 1999. Juran's quality handbook, fifth edition. McGraw Hill, NY. 1872 p.

Lang, Laura. 1998. Managing natural resources with GIS. Environmental Systems Research Institute, Inc., Redlands, CA. 117 p.

Lund, H. Gyde. 1985. Designing inventories to support multiple decisions. Invited paper for international meeting on Forest Resource Inventories: Appraisal Tools for Decision Making held in Venice, Italy, April 26-28, 1985.

Lund, H. Gyde, ed. 1998. IUFRO guidelines for designing multipurpose resource inventories. IUFRO World Series Vol. 8, IUFRO Secretariat, Vienna. 216 p.

USDA Forest Service Strategic IM Team. 1992. Information management: a framework for the future. Washington, DC. 17 p.

APPENDICES

Appendix A—Significant Inventory and Monitoring Efforts of Recent Past

- Resources Evaluation Techniques Project, late 1970s. An integrated, interagency, inventory project in Ft. Collins in response to the Resources Planning Act of 1974.
- Integrated inventories of renewable natural resources workshop, 1/78. Held in Tucson, AZ and sponsored by various federal agencies, including the Forest Service.
- Our Natural Resources: Basic Research Needs in Forestry and Renewable Natural Resources, 1982. Recommended increased focus on managerial sciences and declared that data bases and resource inventories must be current, accurate, and based on sampling rather than a complete listing of all resources.
- Preparing for the 21st Century, 3/84. Forestland inventory workshop held in Denver, CO by the Timber Management Staff that provided input to RICTG (see below).
- Proceedings of Inventory Integration Workshop, 10/84. Held in Portland, OR by the Range and Timber Management Staffs; provided input to RICTG (see below).
- Resource Inventory Coordination Task Group (RICTG), 1984. Chartered to develop the Resource Inventory Handbook (FSH 1909.14), which includes specifications for minimum information (core variables) needed for Forest Plans and national assessments.
- Resource Information Project (RIP), 6/88. Designed to identify and organize basic elements of corporate resource information with objectives to determine current uses of basic information, analyze commonality and differences, and develop standards based on that analysis.
- Interim Resource Inventory Glossary, 6/89. Definitions and codes of what were 'core" variables defined by RICTG (see above)—those that were required to generate reports required by the WO.
- National Workshop on Monitoring Forest Plan Implementation, 5/90. Designed to clarify expectations for monitoring plan implementation on each forest.
- Federal Geographic Data Committee (FGDC), 10/90. FGDC coordinates development of the National Spatial Data Infrastructure (NSDI), which encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data.
- Development of FSH 2090.11, Ecological Classification and Inventory Handbook, 4/91.
- Information Management: A Framework For The Future, 2/92. Provided a vision of a desired future information environment and a process to migrating to it (seven strategies).
- Methodology Consensus Report, 3/92. Fulfilled Strategy #3 of "Framework" report. Selected "CASE" methodology as the standard.
- UNCED, 6/92. United Nations Conference on Environment and Development was held in Rio de Janeiro. Over 170 heads of state attended and issued resolutions on the sustainable use of forests. The Montreal Process and Santiago Declaration (see below) grew out of UNCED.
- First Blue Ribbon Panel on FIA (BRP1), 1992. Recommended shortening the cycle length to five years throughout the United States and reinstalling the strategic grid on national forests where measurements had lapsed.
- Re-establishment of Permanent Plot Grid, 10/92. Memo from Associate Chief George Leonard requiring the re-establishment of the permanent plot grid on NFS lands in the West so that consistent data for RPA assessments could be provided for all ownerships.

- National Monitoring and Evaluation Strategy, 1/93. Provided background and recommended actions for 5 strategies: (1) line officer involvement, (2) link to forest plan goals and objectives, (3) funding, (4) consistency and integration, and (5) partnerships and communication.
- Integrated Ecological and Resource Inventories national workshop, 4/93. Participants agreed on need for nationally consistent ecological classification, mapping, and inventory direction, including standard frameworks, methods, definitions, and data and information management.
- National Monitoring and Evaluation Work Group Report, 9/93. The group defined monitoring and evaluation, identified steps in the monitoring process, stated the objectives of monitoring and evaluation, provided a taxonomy of monitoring and evaluation activities, described problems the agency has in monitoring as well as factors contributing to successful monitoring, discussed and evaluated seven alternative solutions, and recommended a course of action including plans at national, regional, and forest level.
- A Blueprint for Forest Inventory and Analysis Research and Vision for the Future, 10/93. Described plans and relationships with partners necessary to respond to various acts that emphasized making and keeping current comprehensive inventories and analyses of the present and prospective conditions and requirements for the renewable resources of the forests and rangelands of the United States.
- Adoption of National Hierarchical Framework of Ecological Units, 12/93. Acting Chief Dave Unger formally adopted the national hierarchy that began the institutionalization of integrated ECOMAP inventories.
- Common Survey Data Structure (CSDS), 1/94. A field-based, integrated initiative of IREMCG for developing a common data structure to assist in decision-making. Development focused on terrestrial, aquatic, and vegetation components of ecosystems.
- Ecosystem Planning, Inventory, and Monitoring, 10/94. New NFS budget line item established that attempts to make inventories more integrated and provides heightened visibility for monitoring.
- Implementation Master Plan, 12/94. Identified 30 major activities needed to implement fully the "Framework" with due considerations for the ongoing and existing body of work already accomplished in the area of information management and technology.
- Santiago Declaration, 2/95. International agreement on 7 criteria and 67 indicators for the conservation and sustainable management of temperate and boreal forests.
- Inventory & Monitoring Task Team issues report "Charting an Agency Course Toward Integrating Resource Information in Support of Ecosystem Management", 4/95.
- Agency Wide Strategy Stage (AWSS), 4/95. First step in "CASE" methodology. Produced a set of models describing the strategies, business, and information of the agency to serve as a context for coordinating future information development projects. Proposed 17 focus areas.
- Natural Resource Information Strategy Project (NRIS), 6/95. Sponsored by the NFS WO Directors and the EM Steering Group to develop a strategy to manage the Forest Service's sizable investment in natural resource information. This was one of the AWSS' focus areas.
- National Monitoring and Evaluation Coordinator, 7/95. Split position between NFS and Research created and filled in WO to focus attention full-time on monitoring and evaluation.
- Inventory and Monitoring Institute (IMI), 1/96. Officially approved by the National Leadership Team to facilitate and support the collection and management of compatible, scientifically reliable resource information at national, regional, and National Forest planning levels.
- Research Needed by Regions of the United States, to Sustain the Nation's Forests into the Twenty-First Century (Seventh American Forest Congress), 2/96. Prominent need for all regions

was a forest inventory and analysis program with more frequent, more comprehensive, and more consistent measures. Also mentioned for several regions were inventory processes that more adequately monitored forest health.

- Ecosystem Management Information Issue Team (EMIIT), 12/96. Chartered by the EMCT to provide it with staff support on all natural resource information management activities and issues. An outgrowth of CSDS, it began work on 3 projects: (1) terrestrial ecological unit inventory, (2) corporate vegetation database, and (3) core GIS layers.
- Sustainable Development Issue Team (SDIT), 12/96. Chartered by the EMCT to provide a national leadership forum for all aspects of sustainable development, including how to monitor progress.
- Integrating The Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework, 3/97. Final report from a team with Forest Service representation organized by White House agency (CENR of NSTC) that proposed a collaborative integration of the nation's environmental research and monitoring networks to deliver the necessary scientific data and information to produce integrated environmental assessments. It will build upon existing networks and programs, facilitated by any necessary standardization and data-management infrastructure.
- Recommended Core Data Standards for GIS Applications, 10/97. Report to EMCT/IREMCG that identified 15 core layers that each national forest should provide.
- Forest Service Corporate Resource Information Implementation Plan, 11/97. EMCT/IREMCG initiated NRIS and the development of corporate databases.
- Forested Landscapes in Perspective, 1998. National Research Council recommended improving the quantity, quality, and timeliness of information about nonfederal forests and enhancing access to this information.
- Agricultural Research, Extension, and Education Reform Act of 1998, 6/98. Legislation providing explicit direction for Forest Service strategic inventory, esp. Forest Inventory and Analysis.
- Blue Ribbon Panel II on Forest Inventory and Analysis Program (BRP2), 3/98. A report was issued by a cross-section of FIA user groups that criticized FIA and made a series of recommendations for improvement, including greater frequency of surveys and consistent core set of data (including ecological attributes) across all ownerships.
- Integrating Surveys of Terrestrial Natural Resources: The Oregon Demonstration Project, 9/98. An interagency effort demonstrating the feasibility of linking inventories with diverse probability-based samples.
- Strategic Plan for Forest Inventory and Monitoring, 12/98. FIA and FHM's response to the Agricultural Research, Extension, and Education Reform Act of 1998; detailed plans for merging the programs and implementing annual inventories.
- Committee of Scientists report, 3/99. Serving as guidance for revising the National Forest planning regulations, the committee placed strong emphasis on the need for reliable inventory, monitoring, and assessment in order for policies, strategies, and decisions to be built, evaluated, and changed in a scientifically credible manner.
- Proposed Planning Rule, 10/99. Places strong emphasis on the need for scientifically credible inventory and monitoring and evaluation to support assessments of sustainability and adaptive management.

Appendix B—Significant Inventory and Monitoring Efforts Currently Underway

- Criteria and indicators for sustainable management (Santiago Declaration for forest, range for grasslands, and forest management unit pilots)
- Quantifying performance measures for Government Performance and Results Act strategic plan
- Developing inventory and monitoring requirements and protocols for the next generation of resource management plans
- Planning a training course on monitoring forest plan implementation
- Enhancement of the Forest Inventory and Analysis program through annual inventories and inclusion of Forest Health Monitoring plots to respond to the Agricultural Research, Extension, and Education Reform Act of 1998 and to improve consistency, comparability, and coverage.
- Expansion of the Forest Health Monitoring aerial detection surveys, evaluations, and intensive site ecosystem monitoring to all 50 states.
- Large-area assessments developing monitoring protocols (e.g., Sierra Nevada, Columbia River)
- Using regional and national data on America's forests from the FIA and FHM program to prepare the White House report, State of the Nation's Ecosystems, and the United Nations Food and Agriculture Organization Temperate and Boreal Forest Resource Assessment 2000.
- Inventory and monitoring Technology and Development Steering Committee in place and beginning work on priority projects
- FIA and FHM programs developing a standard field manual with protocols for over 70 data elements to ensure consistency and compatibility of data collection and interpretation across the United States.
- Planning to develop wildlife population monitoring protocols in response to increasing level of litigation
- Inventory and Monitoring Institute work with the Northern Region to develop a strategic ecological system inventory that addresses multiple resource issues at various scales
- NRIS data modules developing data migration and inventory standards for legacy and new information, respectively.
- Transforming FIA from periodic inventories to annualized inventories.
- Rewriting the Ecological Classification and Inventory Handbook (FSH 2090.11) to reflect new inventory and monitoring emphases.
- Data collection is underway on many national forests for the 15 core GIS layers that were adopted as agency standards in November 1997.

Appendix C—Sample of Inventory Structure and Relationships

The IREMCG through the EMCT recently commissioned the IMI to conduct a "survey of inventories" to document all of the various inventories that are occurring at the regional level of the organization. Table 1 is an example of a way that the survey information might be displayed.

"Dimension" can be thought of as ecosystem components. There are numerous ways to categorize such components, but here we focus on three basics: physical, biological, and human dimensions. For our example, we will consider the vegetation aspect of the biological dimension.

"Hierarchy" represents a spatial, nested classification; for example a hierarchy of political units would be: nations, states, counties, and townships. Another example is the national hierarchy of ecological units—domain, division, province, section, subsection, landtype association, landtype, and landtype phase. A third example is the vegetation polygon system used at finer scales on the national forests.

"Protocol" includes the "what" and "how" of inventory and monitoring, such as data dictionaries, data standards, quality assurance protocols, and data collection methods. For vegetation, there are a number of such protocols: the FIA strategic inventory procedures, the Federal Geographic Data Committee's vegetation classification standard, the general purpose vegetation protocol used by the Northern Region, protocol for mapping existing vegetation used by the Rocky Mountain Region, and the common stand exam and range inventory protocols used at the fine scale.

"Product" is the basic type of information resulting from inventories. It is accessed through corporate data bases (such as NRIS) or GIS layers. It also includes valuable core metadata in a standard format. In the vegetation example, products are attribute data or mapped vegetation polygons.

Table 1. Sample of inventory structure and relationships.

Dimension	*Hierarchy*	*Protocol*	*Product*
Physical			
Biological			
Vegetation	Political Units, National Hierarchy of Ecological Units/ECOMAP, Vegetation polygons	FIA Protocol, FGDC Vegetation classification Standard, General Purpose vegetation Protocol, Common stand exam or range inventory	Attribute data (with metatdata), Digital and hardcopy maps delineating vegetation polygons (with metadata)
Human Dimensions			

Appendix D—CENR Monitoring and Research Framework

The Committee on Environment and Natural Resources (CENR) of the White House's National Science and Technology Council (NSTC) proposed a framework for integrating environmental monitoring and related research on the Nation's ecological systems and resources (Fig. 4). The framework links systematic observations and monitoring of ecological systems and resources through predictive modeling and process research. These linkages will provide the information needed to better understand, detect, and predict the status and trends in the ecosystems and natural resources of the nation so as to plan for their sustainability. The framework (CENR 1997) states:

> *A fundamental premise of the framework is that no single sampling design can efficiently provide all of the information needed to evaluate environmental conditions and guide policy decisions. A conceptual framework that effectively addresses the multiple scales and processes of the environment can be assembled largely from existing methods that have been designed to monitor various aspects of the environment in the most effective manner possible. Logistical limitations impose inherent trade-offs between the number of variables that can be measured, the frequency at which they can be measured, and the number of sites involved. These constraints lead to a hierarchical structure for the monitoring framework, which can be represented by a triangle, with the measurements that can be made at the greatest number of sites at the base of the triangle.*

There are five key components to this triangle, all of which apply to various aspects of current FS inventory and monitoring activities. At the base of the triangle are inventories based on remote sensing-- methods that can collect data for specific properties simultaneously and uniformly across large regions. Through analyses and interpretations, measurements can be transformed into parameters of interest, including cover type and density, soil properties, and density of development. Often, these data are mapped and subjected to additional spatial or mathematical analyses. Comparisons of data collected on different dates can be used to evaluate rates of change.

The middle layer of the triangle represents resource surveys based on sampling populations. Data collected through probabilistic surveys are designed to characterize specific properties of a region by sampling a subset of the total area, rather than the entire area. Examples are the FIA and FHM programs. Probabilistic surveys are designed to address specific resources or environmental issues. The data are most useful for analyses at the state, regional, and national levels. Sampling at the intensity required to draw powerful local conclusions is often prohibitively expensive over an entire region.

The apex of the triangle is for intensive monitoring and research sites. Data from these sites provide a greater number of properties and are collected at a higher frequency (e.g., daily, weekly, or monthly) than the data collected at other levels, but at a much smaller number of locations. Examples are data from long-term ecological research (LTER) sites, such as Coweeta Hydrologic Laboratory or the H.J. Andrews Experimental Forest. The critical feature of intensive monitoring and research sites is that all of the major potential causes of environmental change are measured at the same location. This level is essential for understanding processes that occur at local scales and within time periods much shorter than measured at the other two levels.

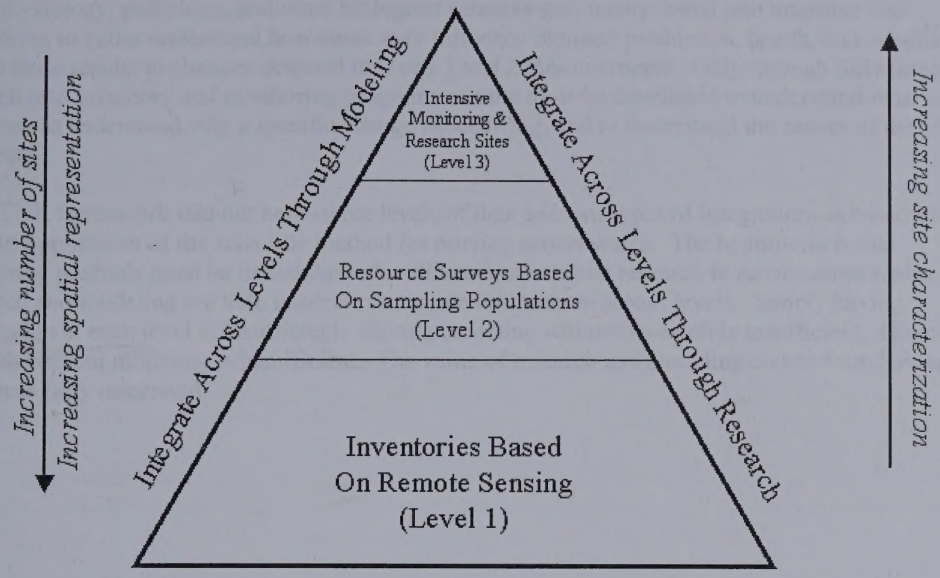
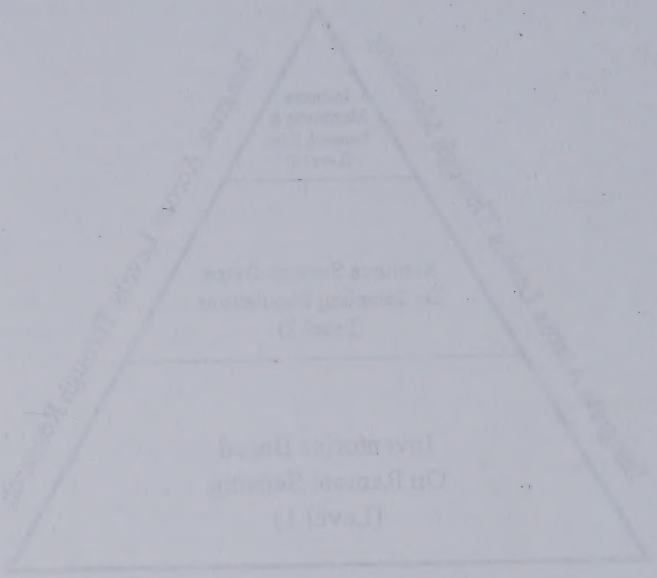

Increasing number of sites
Increasing spatial representation
Integrate Across Levels Through Modeling
Intensive Monitoring & Research Sites (Level 3)
Resource Surveys Based On Sampling Populations (Level 2)
Inventories Based On Remote Sensing (Level 1)
Integrate Across Levels Through Research
Increasing site characterization

Figure 4. Conceptual framework for achieving the goals of environmental inventory and monitoring at multiple scales (CENR, March 1997).

Not one of the levels, by itself, can function effectively as an inventory and monitoring system. The key to creating an effective inventory and monitoring system is integrating information across levels. Modeling and research are the integrating components that make this system work. For example, within level 1, sets of photography or satellite imagery from different points in time can be used to detect changes. However, such comparisons cannot generally indicate why a specific change occurred. Data from levels 2 and 3 are essential for quantifying the extent, distribution, condition, and rate of change of specific environmental properties and for understanding change processes over large areas. To successfully link information from photography/videography/imagery and the probabilistic surveys of field sites, researchers have developed a number of models that integrate the information. Some of the models focus on accurate classification of cover types, others on estimating area, growth, mortality, removals, total biomass, productivity, and so forth. All of these models require validation--which can only be done with data from probabilistic surveys--followed by peer review. The ability to make, and the credibility of, "wall-to-wall" estimates from level 1 imagery are dependent on successful integration through modeling of data from the other levels.



Research is a necessary precursor and often an adjunct to modeling that operates at several different levels in the context of an inventory and monitoring framework. At one end of the spectrum, research on new sensor designs helps determine what imagery might become available and how to best take advantage of increased image resolution. At the other end of the spectrum, basic research results in plant physiology, pathology, and other biological sciences gets incorporated into intensive site monitoring to better understand how stress may influence biomass production, health, and condition and relates those results to changes detected in levels 1 and 2 measurements. Only through fully integrating research into inventory and monitoring programs can the tools be developed to understand what is observed, to understand why a specific change is occurring, and to understand the causes of the effects observed.

The CENR framework laid out here--three levels of data and two types of integration--is based upon a rigorous application of the scientific method for moving across scales. The hypothesis is that monitoring methods must be linked through validated models and research to move across scales. Research and modeling are both needed to integrate information across levels. Simply having information at each level is insufficient. Having modeling without research is insufficient. Having research without modeling is insufficient. The value of research and modeling comes from having all the pieces fully integrated.

Appendix E—Glossary

bioregional assessment: there is no clear definition at this time, the term is frequently used interchangeably with ecoregion assessment. The Committee of Scientists purposefully chose to not define the term and accept ecoregional assessment as a synonym. With that caveat bioregional assessment can be somewhat described as: assessment of biological (and physical) conditions of life and other living species in the area in which they live presumably in order to exercise greater care in the use they make of the bioregion. (Based on Bioregional Assessments, Science at the Crossroads of Management and Policy, K.N. Johnson, et al. 1999)

customer: Anyone who is affected by the product or by the process used to produce the product. Customers may be external or internal. (Juran, 1998)

deficiency: Any fault (defect or error) that impairs a product's fitness for use. (Juran, 1998)

ecology: 1. The study of the relations of organisms to one another and to their surroundings. 2. The study of the interaction of people with their environment. (Oxford dictionary of current English)

ECOMAP: Ecoregional map classification

ecoregional assessment: assessment of biological organisms and their surroundings including the interactions of people with their environment in terms of ecological, social, and economic systems. (no particular source, just a mix of 'bioregional assessment' and 'ecology' with a people twist)

EPA: Environmental Protection Agency

forest inventory: 1. A set of objective sampling methods designed to quantify the spatial distribution, composition, and rates of change of forest parameters within specified levels of precision for the purposes of management. 2. The listing (enumeration) of data from such a survey - synonym cruise, forest survey -- note inventories may be made of all forest resources and including trees and other vegetation, fish, insects, and wildlife, as well as street trees and urban forests trees (Helms 1998)

FWS: Fish and Wildlife Service

integrate: combine (parts) into a whole (Oxford dictionary of current English)

integrated inventory: a compilation of resource-specific inventories that can be integrated through analysis techniques and tools such as applications of GIS. Also, coordinated collection and storage of inventory measurements and observations into a unified and well-defined data management system.

integrated resource inventories/resource monitoring: inventories designed to meet multiple needs for information and consist of "...data collection for analysis of the status or conditions of resources or other vegetative or physical characteristics required for planning..." (FSH 1909.4). Several types of integrated inventories are utilized for forest planning: Physical Dimensions (Terrestrial and Aquatic Ecological Units, both linked to National Hierarchical Frameworks and Air Quality Related Values), Biologic Dimensions (Existing Vegetation, Terrestrial Fauna, and Aquatic Biota), and Human

Dimensions (Recreation Use, Heritage, Social, and Economic data). Integrated resource inventories provide a scientific basis and ecological context for landscape and watershed analysis for Forest planning activities. (From FY 2000 Planning and Budget Advice, USDA Forest Service draft 8/31/99)

inventorying: gathering data needed for analyses and evaluation of the status or condition of a specific universe or area of concern (From Resource Conservation Glossary, 2nd edition, 1982. Soil Conservation Society of America, Ankeny, Iowa)

monitoring: the collection of information over time, generally on a sample basis by measuring change in and indicator or variable, to determine the effects of resource management treatments in the long term (Helms 1998)

monitoring program vs. repeated inventories: Many people suppose monitoring occurs when an inventory is repeated. This is not necessarily the case. Monitoring should include goals toward which comparisons are made, thresholds for changes detected, and proposed actions that would be undertaken in the event thresholds are met for any item of interest being monitored. (Patrice Janiga)

NRCS: Natural Resource Conservation Service

resource inventory: Collection of data for analysis of the status or condition of resources (From Resource Conservation Glossary, 2nd edition, 1982. Soil Conservation Society of America, Ankeny, Iowa)

scientific credibility within an inventory program: the combination of (1) tested and accepted protocols, (2) quality assurance practices, and (3) quantification of uncertainty throughout the design and implementation of an inventory (including analysis phases and portrayal of uncertainty associated with products (information, maps, reports) from an inventory program

In the world of managing for quality, there is still a notable lack of standardization of the meanings of key words. Any organization can do much to minimize internal confusion by establishing its own glossary. Also, definitions of words do not remain static as philosophies and understanding of quality evolve. "Quality" means those features of products, which meet customer needs and thereby provide customer satisfaction. The purpose of higher quality is to provide greater customer satisfaction, however providing more and/or better quality usually requires an investment and hence usually involves increases in costs. "Quality" means freedom from deficiencies - freedom from errors that require doing work over again or that result in field failures, customer dissatisfaction, customer claims, and so on. (Juran, 1998)

system: complex whole; set of connected things or parts; organized body of things (Oxford dictionary of current English)

systems approach to inventory: a methodical process of inventory design that encompasses the parts of systems (ecological, social, and economic) and the processes associated with the relations among these parts that results in the ability to be responsive through time and across scales and to be a sound foundation upon which special surveys can be built to respond to the myriad of issues that arise over time.